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**Subject:** Pandora moth on the North Kaibab RD

**To:** District Ranger, North Kaibab RD, Kaibab NF

On August 27, 2008, Mary Lou Fairweather (Arizona Zone Plant Pathologist) and I (Arizona Zone Entomologist) conducted a site visit to review potential forest health projects on the North Kaibab Ranger District (see site visit report dated October 24, 2008). While filling our vehicle with gas at Jacob Lake, we observed several male and female pandora moths around the gas station apparently attracted to the lights (***Figure 1***). Based on this observation, and because pandora moth has a history of causing heavy defoliation on the North Kaibab, it was decided that our staff should return later in the fall to conduct population surveys. I describe in this report the results of our subsequent visit to the District to measure immature stage population densities in the vicinity of Jacob Lake and provide information on pandora moth biology and outbreak impacts.

***Figure 1.*** *Female pandora moth and eggs found on gas pump at Jacob Lake, AZ.*

## *Current status of Pandora moth on North Kaibab Ranger District*

On October 8-9, 2008, John Anhold (Arizona Zone Forest Health Leader), Bobbe Fitzgibbon (Arizona Zone Entomologist), and I surveyed several locations around Jacob Lake for pandora moth (***Figure 2***). Heavy levels of defoliation occurred throughout this area during the last outbreak in the late 1970's – mid 1980's (Bennett 1983). Our survey consisted of examining ten relatively open-grown, sapling to pole-sized ponderosa pine trees per site per person (30 trees total per survey site). The lower crown of each tree was scanned for a period of two minutes to look for egg clusters and young larvae. We found 5 to 30 percent of trees sampled at each site had at least one egg cluster or larval colony. Across all sites, approximately 15 percent of the surveyed trees had at least one egg

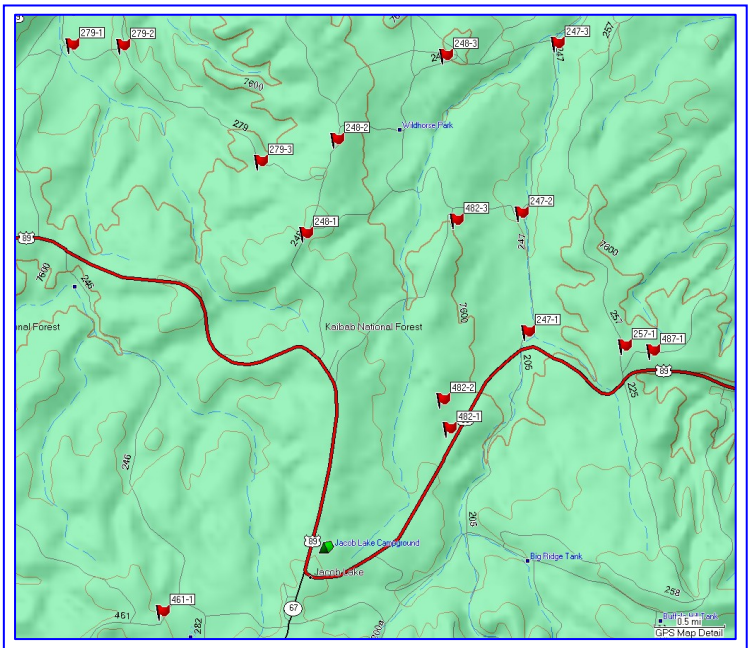


***Figure 2.*** *Location of sites that were surveyed for pandora moth egg clutches and larval colonies near Jacob Lake, AZ.*

clutch or larval colony. The egg mass and larval colony densities per tree we observed were significantly lower than in 1980, 1982, and 1984 on the North Kaibab RD, when up to 13 egg masses where found per branch (Schmid and Bennett 1988). Our findings indicate a widespread distribution of low population levels and likely the initial phase of a building pandora moth population.

We also surveyed two sites near Walhalla Overlook of the Grand Canyon National Park. A smaller pandora moth outbreak occurred in that area in the late 1980's (Parker 1989). We found no evidence of pandora moth at these sites.

## *Pandora moth description and biology*

Adult pandora moths are very large and heavy bodied, about 2.5 to 4.0 cm long, with a wingspread of 7.0 to 11.0 cm (Carolin and Knopf 1968). The forewings are brownish gray and hindwings are light pinkish gray, each marked with a black dot and a dark wavy line. The males are distinguished by having large, feathery antennae. The globular eggs, bluish green to bluish gray, are deposited in clusters of 2 to 50. There are five larval instars and all have characteristic spines. Early instar larvae are about 5 mm long (***Figure 3***). They have shiny black heads and black to brownish bodies that are covered with short, dark hairs. Fifth instar larvae grow to about 6.0 to 8.0 cm long and are brown to yellowish green. Pupae are dark purplish brown, 2.5 to 3.5 cm long, and have a tough shell.

***Figure 3.*** *Newly emerged pandora moth larvae (left) feed in small colonies from the distal end of the needle toward the fascicle. Mid- (right) and late-instar larvae feed in smaller groups or solitarily.*

Pandora moth has a two-year life cycle. Adults emerge in July through August. The moths mate and females deposit their eggs within a few days. Females lay 80 (Carolin and Knopf 1968) to more than 150 (Schmid and Bennett 1988) eggs, which are distributed in several clusters on needles, bark, and neighboring vegetation. The average number of eggs per cluster was 11 to 15 during the early 1980's in (Schmid and Bennett 1988). The egg stage lasts about 40 days and most larvae emerge by early October in Arizona. Larvae are gregarious and extremely cold hearty. They feed in groups on the foliage on warm days throughout the winter. Larvae disperse several times throughout tree crowns to optimize their development through temperature and feeding effects. Fifth instar larvae leave the host trees in late June and enter the ground where they pupate. They remain in the pupal stage for the next 12 to 13 months.

Because pandora moth has a 2-year life cycle with pupation lasting 1 year or more, defoliation occurs primarily in odd years (2009, 2011) and moth flights take place in even years (2008, 2010) in Arizona. However, a proportion of the population remains as pupae for 2 or more years (Gerson et al. 1999) and therefore is asynchronous with rest of the population. In some areas of Oregon and California principal moth flights occur in odd years and defoliation takes place in even years.

## *Pandora moth outbreaks*

Pandora moth is widespread in pine forests from Arizona and Colorado to Oregon and California, and periodically exhibits large population outbreaks (Patterson 1929, Wygant 1941, Carolin and Knopf 1968, Schmid and Bennett 1988). Outbreaks occur at intervals of 20-30 years and typically last 6-8 years (Patterson 1929, Schmid and Bennett 1988, Speer et al. 2001). Outbreaks are generally limited to pine forests having loose (volcanic or pumice) soils because caterpillars need to bury themselves prior to pupation (Carolin and Knopf 1968) and this may be an adaptation to avoid mortality caused by surface fires. Defoliation events can significantly affect tree growth and health (Bennett et al. 1987, Cochran 1998, Speer and Holmes 2004), and can predispose trees to colonization by bark beetles and pathogens (Patterson 1929, Carolin and Knopf 1968). However, because defoliation is typically limited to older needles and occurs every other year, the effects are somewhat moderated.

The last outbreak on the North Kaibab Ranger District encompassed > 30,000 acres in the late 1970s through the mid 1980s and was centered around Jacob Lake (Schmid and Bennett 1988). Although nearly all trees within the outbreak area were defoliated to some degree, larval numbers were greater on relatively level ridgetops than in adjacent ravines (Schmid and Bennett 1988). This pattern was probably caused by egg laying preference of moths. While ponderosa pine was the primary host, piñon were also defoliated when the outbreak reached the ponderosa-piñon-juniper ecotone. Growth of ponderosa pine was more adversely affected in trees >14 inches in diameter at breast height (dbh) than trees <14 dbh (Bennett et al. 1987). While tree mortality was limited during the last outbreak in Arizona (Schmid and Bennett 1988), defoliated trees heavily infected with dwarf mistletoe sustained higher levels of mortality (Wagner and Mathiasen 1985). Perhaps more importantly for developed recreation sites and heavily visited areas, such as Jacob Lake and the Grand Canyon National Park, are nuisance and visual impacts to visitors, and economic impacts to businesses within the affected area (Krisko 1988, Schmid and Bennett 1988).

## *Managing pandora moth*

Few options currently exist for managing pandora moth populations (Torgersen 2001), and direct suppression (synthetic insecticides, thinning, burning) is unlikely to terminate an outbreak (Ragenovich et al. 1986, Schmid and Bennett 1988, Ross 1995, Gerson and Kelsey 1997). Previous suppression strategies on the North Kaibab RD used aerial applications of the insecticide acephate (Bennett et al. 1984, Ragenovich et al. 1986). Spray projects in 1981 and 1983 reduced populations and decreased defoliation where visual quality was a concern; however, they had little effect on the overall course of the outbreak (Schmid and Bennett 1988). Schmid and Bennett (1988) suggest that silvicultural treatments that maintain desirable stocking levels and reduce the incidence of dwarf mistletoe will reduce growth and mortality losses, but silvicultural strategies will not suppress outbreaks because stand structure and tree size does not influence egg laying behavior or larval survival. Because the pupal stage of pandora occurs for an extended period of time in the soil it was hypothesized that prescribed burning could be used as a control strategy. However, fuel and weather conditions have been found to limit the effectiveness of this approach (Miller and Wagner 1984, Schmid and Bennett 1988).

Pandora moth populations during previous outbreaks usually collapsed due to the effects of a pathogenic virus called nuclear polyhderosis virus or NPV (Wygant 1941, Schmid and Bennett 1988). Effects of insect pathogens such as NPV typically act in a delayed density dependent

fashion resulting in lag time between host population outbreak and pathogen transmission throughout the population (Federici 1999). Therefore, heavy defoliation can be expected for 2 to 3 generations before populations collapse. A *Telenomus* species (Hymenoptera) was also an important parasite of pandora moth eggs during the previous outbreak on the North Kaibab (Schmid and Bennett 1988).

## *Conclusions*

At current population levels we expect there to be no visible or only minor defoliation from aerial detection surveys during the 2009 larval period. If an outbreak progresses according to previous outbreak patterns, heavy defoliation should occur in 2011 and 2013. We will continue to monitor populations and defoliation through ground and aerial detection surveys on the Kaibab NF and Grand Canyon National Park in 2009. We are also available to work with the North Kaibab RD to develop informational and educational materials for public distribution. We will be putting together a pest alert this winter that we will make available as well.

It is important to note that impacts measured during the previous outbreak occurred during above average precipitation and cool conditions (Schmid and Bennett 1988), and therefore we may have not fully realized what impacts can occur under different climate scenarios. Because drought conditions (increased annual temperatures and dry, warm winters) have occurred in the Southwest since the mid 1990s, plus altered forest structure and intensification of dwarf mistletoe, it is possible the severity and extent of the next outbreak will be more severe than previous outbreaks.

If you have any questions regarding my assessment or my recommendations, please let me know.

*/s/ Joel D. McMillin*
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